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Electro-Magnetic Telegraphs, &c.

LETTERS PATENT to Charles Wheatstone, of Hammersmith, in the County of Middlesex, for the Invention of "IMPROVEMENTS IN ELECTRO-MAGNETIC TELEGRAPHS AND APPARATUS USED FOR TRANSMITTING SIGNS OR INDICATIONS TO DISTANT PLACES BY MEANS OF ELECTRICITY."

Sealed the 2nd August 1858, and dated the 2nd June 1858.

PROVISIONAL SPECIFICATION left by the said Charles Wheatstone at the Office of the Commissioners of Patents, with his Petition, on the 2nd June 1858.

I, CHARLES WHEATSTONE, of Hammersmith, in the County of Middlesex, do hereby declare the nature of the Invention for "IMPROVEMENTS IN ELECTRO-MAGNETIC TELEGRAPHS AND APPARATUS USED FOR TRANSMITTING SIGNS OR INDICATIONS TO DISTANT PLACES BY MEANS OF ELECTRICITY," to be as follows:—

On January 21st, 1840, a Patent was granted to myself and Mr. W. F. Cooke for "Improvements in Giving Signals and Sounding Alarums by Means of Electric Currents:" the Specification of this Patent contained the description of electro-magnetic telegraphs, in which the letters of the alphabet or other characters were indicated by a moveable hand pointing to them on a fixed dial, or by a moveable dial presenting the characters behind a fixed aperture. In one form of instrument the hand or dial was caused to advance step by step by the action of an electro-magnet on an armature of soft iron, in another by the action of alternately inverted currents on magnetic needles moved alternately in opposite directions. Instruments there called communicators for working these signal telegraphs were also described, one acting by voltaic electricity, the other by magneto-electricity.

In the Specification of the Patent for which I am now applying, I propose to describe various new improvements on electro-magnetic telegraphs, constructed on the same general principles, and on other electro-magnetic instruments to which the same modifications are applicable.

The first part of my Invention relates to improvements in the signal instrument, the main object of which is to cause its movements to be effected with greater steadiness, certainty, and rapidity than hitherto, and especially with electric currents or shocks of less energy than have hitherto been employed for such purpose, whether proceeding from a voltaic battery a magneto-electric machine, or any other applicable source of electric power.

The first improvement is in the construction of the mechanism which converts the oscillatory motion of a magnetic needle or bar, or the armature of an electro-magnet, into the rotary step-by-step motion of the hand. This mechanism is constructed of great delicacy and lightness so that a small force will cause it to act efficiently, and the improved forms of propelment which I have adopted are intended to cause the hand to move with regularity, so that either jumps or cessations of action shall be less liable to occur; I use the word propelment in contradistinction to escapement, which requires a maintaining power for its action. In one method the two pallets which act on the propelling wheel have each an independent motion moving as levers round fixed axes; their longer ends act on the inclined teeth of the wheel at opposite points of its circumference, and their shorter ends are connected by a hair spring. A pin attached to the axis of the magnetic needle or bar or the armature of the electro-magnet acts in its alternate motion on each pallet, and presses it firmly against a tooth of the wheel, while at the same time the hair spring presses the other pallet against the opposite tooth, but so lightly and yieldingly as to offer no sensible impediment to its motion. By this construction greater certainty and regularity in the motion of the hand is ensured than when the pallets are rigidly attached to each other. In a second method the axis of the propelling wheel, instead of being fixed, is attached to the end of a short lever, the other arm of which is acted upon by a pin connected with the axis of the magnetic needle or bar, or the armature of the electro-magnet. The two pallets which act on straight teeth at opposite points of the circumference of the wheel are fixed so that the rotary motion of the wheel is occasioned by the lever to which it is fixed being moved with it towards the two pallets alternately; the motion being limited by two fixed pins, against which the pallet wheel impinges at the opposite limits of its oscillation. Each pallet consists of a very light spring placed tangentially to the circumference of the wheel, and readily yields to a tooth passing beneath it when the opposite tooth is propelled by the other pallet, and then falls in its place ready to propel the tooth which has passed beneath it. To prevent the oscillatory motion of the wheel being communicated to the hand, the axis of the latter is attached from that of the former, and is caused to rotate by means of a driving pin attached thereto.

The second improvement is in the construction of the electro-magnetic arrangement employed to produce the motions of the step-by-step index and dial telegraphs, and is equally applicable to other forms of electro-magnetic telegraphs and alarms. Two magnetic needles or bars with their poles in opposite directions are placed near each other on opposite sides of and parallel to the axis round which they move; two straight electro-magnets are placed one on each side of the axis of motion of the needles and parallel thereto; when a current is transmitted through the coils of these electro-magnets in such manner that the adjacent poles of each shall have at the same time opposite polarities, the dissimilar poles of the two needles are simultaneously acted upon, so that each of their poles is attracted by one pole of one electro-magnet, and repelled by one pole of the other electro-magnet, the attracting and repelling actions all conspiring to move the axis in the same direction. Instead of being straight, the magnetic needles or bars may be curved inwards towards each other, so that their weight shall be thrown nearer the axis of motion. By this construction the force of the electro-magnets is applied near the axis of motion of the magnetic bars instead of at a considerable distance from it, as is the case when electro-magnets are applied to the poles of a straight magnetised bar moving on an axis to which it is perpendicular; another of its advantages is, that the moving parts being balanced, the attraction of the residual magnetism remaining in the electro-magnets after the current has ceased, is sufficient to hold the needles with firmness even in spite of concussions. While the principle of this electro-magnetic arrangement remains it admits of various modifications. 1. The magnetic needles or bars may be inclined to each other at a small angle crossing at the axis of motion, their opposite poles being at opposite sides of the axis. 2. A single magnetic needle, balanced or unbalanced, may be employed in conjunction with two electro-magnets, or a single electro-magnet may be used in conjunction with two magnetic needles. 3. Instead of the electro-magnets being parallel to the magnetic needles or bars, they may be curved so that their two poles shall act, one attracting, the other repelling, on the poles of the magnetic needles between them. 4. Several such pairs of balanced magnetic needles may be fixed on the same axis, the poles of those adjacent being of opposite kinds, so that the planes in which they lie shall be at equal angular distances from each other. As many straight electro-magnets as there are needles are placed parallel to the axis, and in the angles between them, and the wires are so disposed that when the current in either direction passes through the coils the joint attracting and repelling actions drive the needles to move round the axis in the same direction. In such arrangements there must be an even number of magnetic needles and electro-magnets.

The third improvement consists in a modification of the apparatus of the second improvement before explained, which renders it capable of acting upon another circuit, so as alternately to invert the current originating from a voltaic battery interposed therein, in order to produce simultaneous and corresponding motions in another similar apparatus, forming part of a signal telegraph at a distant station. For this purpose, the axis on which the magnetic needles or bars are mounted is made in two parts, connected together by a piece of ivory or other insulating material, and one end of the axis is in connection with one pole of the battery, and the other end is in connection with the other pole of the battery. Of the magnetic needles or bars mounted on the axis, one is in metallic connection with one part of the axis, and the other is in metallic connection with the other part, and each of these needles is carefully insulated from the part of the axis with which the other is in metallic contact. When by the passage of a current or shock in the line wire, and consequently in the coils of the relay instrument the magnetic needles or bars are caused to move, each of them comes in contact with a spring stop in connection with the wires of the circuit which the relay instrument is to complete, and this circuit is so completed. If now by a current or shock passing in the line wire in a direction opposite to that which produced the first motion, the magnetic needles or bars are caused to move in the other direction, then they come in contact with two other spring stops, so as to complete the circuit in the opposite direction.

The second part of my Invention relates to improvements in the communicator or apparatus for transmitting into the telegraphic circuit the proper number of currents or shocks required to indicate the various letters or characters, whether the source of power be a voltaic battery, a magneto-electric machine, an electro-magnetic machine, or any other kind of rheomotor, and to improvements in magneto-electric and electro-magnetic machines employed in conjunction therewith.

The fourth improvement is a new construction of the communicator when a voltaic battery is employed; it may be considered as a modification of that figured and described in the Specification of the Patent granted to myself and Mr. W. F. Cooke on the 21st of January 1840. It differs therefrom in the following particulars:—1stly. It alternately inverts the currents instead of transmitting to the telegraphic circuit successive currents in the same direction. 2ndly. The alternation of conducting and insulating contacts are done away with. 3rdly. The letter circle or wheel, which in the former is solid, consists of a number of flexible spokes or radii corresponding to the different letters or signs employed proceeding from a common centre, and each carrying at its free extremity a finger pin; when any letter is required to be indicated, the spoke on which it is engraved is moved by means of the finger pin at its extremity so as to give the wheel a rotary motion, and is at the same time pressed down, so that a prolongation of the finger pin comes in contact with a fixed stop, and thus prevents the continuance of the motion. Instead of flexible spokes with fixed pins at their extremities, as here described, the rigid wheel may be retained, and stops or pins may be arranged on its circumference with springs so fixed to them that they may recover their original positions when the pressure of the fingers is removed.

The mechanism for producing the alternation in the direction of the currents admits of considerable modifications. I will describe one of the simplest and most efficient methods:—A toothed wheel is fixed to the axis of the letter wheel of the communicator, so as to rotate with it; this gears into a pinion, which during one revolution of the wheel rotates half as many times as there are letters engraven upon it. On the axis of the pinion is a small grooved disc insulated from it, and carrying a short pin fixed parallel to the axis; the axis of the pinion is placed between two spring bars insulated from each other, and as it rotates, the pin raises each of them alternately, and becomes respectively in metallic communication with them; while the pin is raising one spring bar, the other rests on the axis of the pinion; a spring also rests upon the insulated grooved disc of the pinion.

The terminal wires of the battery are brought to binding screws in metallic communication with the axis of the pinion and with the spring bar, which rests on the insulated disc respectively, and the terminal wires of the telegraphic circuit are brought to binding screws in metallic communication with the two spring bars on which the pin of the pinion acts. This construction of the communicator is equally adapted for working the step-by-step telegraphs, either when the direct current of a voltaic battery is employed, or when induction currents are made use of. In the latter case the terminal wires of the voltaic battery are to be brought to the binding screws, which are in connection with the spring bars. The terminals of the primary coil of an induction apparatus are to be fastened in the binding screws, which are in metallic communication with the pinion and its insulated disc, while the terminals of the telegraphic circuit are to be brought in permanent connection with the terminals of the secondary or induction coil. By this arrangement the battery circuit is never broken. When the current is not transmitted to the telegraphic wires it continues to circulate for a moment in a short closed circuit; thus the spark which occurs on breaking the circuit is obviated.

The fifth improvement consists in the application of the letter circle described in the fourth improvement, in combination with a magneto-electric machine instead of with a voltaic battery. The axis of the letter circle is so geared with the armature of the magneto-electric machine that during one revolution of the former the shocks are inverted as many times as there are letters engraved on the circle. Communicators thus constructed are efficient only when the magnets are of comparatively small dimensions.

The sixth improvement consists of new methods of constructing the communicator when a magneto-electric or an electro-magnetic machine produces the currents or shocks, which are transmitted by its means into the telegraphic circuit. In this improvement the armature of the permanent or electro-magnet is kept in continuous motion by the hand of the operator, or by being connected with any moving power, and finger stops corresponding with the letters on the dial of the telegraph being respectively pressed down regulate the passage of the currents or shocks into the telegraphic circuit for the purpose of acting on the detached telegraph. By this means, however large and powerful the magnet which is employed may be, the operator may act upon the finger keys with the same facility, which would not be the case were the motion of the armature itself to be arrested thereby. The two principal mechanical arrangements by which this improvement is effected are the following:—In the first construction the axis of the armature of the magnet is independent of the axis which carries the index, but is capable of being geared thereto by the depression of either one of a series of finger stops or keys arranged round the apparatus, and corresponding with the letters of the alphabet; this action also disjoins a cross connection, and thus allows the currents generated in the coils of the armature, which were before confined to a short circuit, to pass into the telegraphic line, and projects forward a lever corresponding with the stop or key into such a position that a spring catch carried by the axis of the index when it is brought opposite to it by the revolution of its axis strikes it, and by so doing it sets free the stop or key previously held depressed; on the release of the key, the cross connection which diverts the currents from the telegraphic circuit is recompleted, and the axis carrying the arm with the spring catch is thrown out of gear with the axis of the armature; but while the index is passing from the point at which it is thrown into gear to the point at which it comes in contact with the lever projected forward by the stop or key, the requisite number of shocks or currents have passed into the telegraphic circuit. The gearing between the armature axis and the axis of the index is such that when it is in operation the index axis rotates at the same speed as the hand or index of the receiving instrument. In order that imperfect currents may not be thrown into the telegraphic circuit, the apparatus is so arranged that the axis of the index is not at all times thrown into gear with the armature axis immediately on the depressing of the stop or key. If the armature is not in a proper position for communicating a shock or current, the toothed wheel in connection with the index axis is prevented from falling into gear with the toothed wheel in connection with the armature axis until the moment at which the inversion of the current takes place. In a second method of construction, the arbor which is geared with the axis of the armature carries a toothed wheel; an arm, to which the index is fixed, moves freely round this arbor, and is carried with it when any tooth of the wheel is in contact with a spring catch at the end of the arm, and the telegraphic circuit is complete all the time this contact lasts. The index arm is separately stopped by pressing down either of the finger stops while the arbor and all the other parts connected with it continues its motion, and the transmission of the currents to the telegraphic circuit remains interrupted so long as the motion of the arm is arrested. As the circuit is not completed when the arm is released, but at the moment when the contact is made between the tooth of the wheel and the catch of the arm which corresponds with the moment of the inversion of the current, imperfect currents are prevented from entering into the circuit. As in this construction the currents continue to pass into the telegraphic circuit so long as a key is not pressed down, a provision is made for keeping the stop, which corresponds with the sign indicating the termination of a message, permanently depressed when required, and which at the same time completes the telegraphic circuit, omitting from it the coils of the armature of the magnet. To avoid this additional movement, which has to be attended to by the operator, another contrivance is adopted by which any one of the finger stops being depressed it remains so, even when the finger is removed until another stop is touched, when the former is restored to its normal position. This is effected by an endless chain passing round a series of friction rollers so placed that it forms a circle concentric with the circle in which the finger stops are arranged. The finger stops are so constructed that when either of them is depressed it presses against the endless chain and tightens it, and when another stop is subsequently depressed, and bears in like manner against the chain, the flexure made by the first step is obliterated, and the stop restored to its normal position. It is the peculiar character of these magneto-electric communicators that none of their parts are mechanically connected with the signal telegraph of the transmitting station, as in some arrangements which have been previously proposed, but the former is complete in itself and entirely independent of the latter, except by its action upon it, in consequence of the transmission of the currents through the conducting wire.

The magneto-electric or electro-magnetic machine I usually adopt for the communicators forming the fifth and sixth improvements is of the ordinary construction with a rotating armature. In this disposition four shocks or currents are available during each revolution of the armature, the first two following being in one and the same direction, and the next two following being in the opposite direction. No contrivance is here required to invert or to stop out the alternate currents, the two successive currents in the same direction give additional security that the index of the telegraph shall advance a single step. Either of the following new forms of the magneto-electric machine constituting the 7th, 8th, and 9th improvements may be substituted for the one above mentioned.

The seventh improvement is a modification of the magneto-electric machine, in which instead of the armature revolving before the poles of a magnet, it is caused alternately to approach to and recede from them by means of a cam fixed to a wheel, or by other suitable means. If a single magnet is employed, a contrivance for alternately inverting the direction of the currents must be had recourse to, but this is unnecessary when the armature oscillates between the poles of two similar magnets, so disposed that the currents shall pass through the circuit in opposite directions according as the armature moves towards one or the other magnet. This method may be advantageously applied to the communicator of the 5th improvement as the motion of the letter wheel may be more immediately and certainly stopped at any required point, in consequence of there being no momentum generated by the rotation of the armature.

The eighth improvement consists of a construction of the magneto-electric machine, in which neither the magnet nor the coil of wire is put into motion, but only the soft iron core which is enveloped by the wire. A coil of insulated wire is fixed, and within it is fitted a cylindrical core of soft iron capable of rotating on its axis without carrying the coil with it. The opposite ends of this soft iron core have lateral prolongations also of soft iron; these are of equal length, are at equal angular distances from each other, and extend over the ends of the coil so as to be brought in close proximity to the poles of a magnet, those at opposite ends to opposite poles. On causing the core to rotate once, as many double currents are produced in the coil as there are prolongations on each end of the soft iron cylinder. Instead of a single magnet several may be arranged with their poles in two parallel circles, and placed at distances from each other corresponding with the distances of the prolongations; by this means the strength of the currents is considerably augmented. If the poles of the magnets contained in the same circle are similar, the successive currents are alternate in direction and unequal in intensity, but if the poles are alternately dissimilar two currents in one direction are followed by two currents in the opposite direction available for the purpose required; in the latter case the number of the magnets must be even, and the angular distances of the prolongations must be double the angular distances of the magnetic poles, so that they shall not be at the same time opposite adjacent magnets.

The ninth improvement consists in substituting for a single magnet and armature in any of the magneto-electric machines employed for working telegraphs, several magnets and armatures so arranged that the instantaneous currents or shocks originated by each shall be produced simultaneously, and pass through the same conducting wire. A number of small magnets and armatures thus combined will produce a more efficient result than a single magnet and armature of proportionate dimensions. Electro-magnets may be substituted for permanent magnets in any of the modes of construction described as the 7th, 8th, and 9th improvements.

The third part of my Invention relates to improvements in electro-magnetic alarums, clocks, and registers or counters.

The tenth improvement consists in the application of the electro-magnetic arrangements described under the second head of my improvements to the withdrawal of detents for the purpose of permitting alarums to sound.

The eleventh improvement consists of appropriate mechanism to prevent the detent of an electro-magnetic alarum from escaping until several currents or shocks have been sent through the circuit, and consequently until the magnetic bars have moved to and fro several times. For this purpose the electro-magnetic apparatus is caused to actuate a species of escapement, which at each movement allows to escape one tooth of a short rack in connection with the alarum. By this arrangement one or more accidental jars will not cause the detent to escape.

The twelfth improvement consists in an appropriate mechanism to prevent the hammer of a bell from moving, unless the magnets are acted upon by the electric force. The sounding of the bell is thus rendered independent of accidental shakes or jolts. For this purpose a pin is fixed to the periphery of the toothed wheel, which gives vibratory motion to the hammer in such a position that just as the motion of this wheel is arrested, when the alarum ceases to sound, the pin acts on a catch, and places it so as to restrain or limit the vibrations of the hammer arising from concussions to which the instrument may be subjected. When the alarum is next acted on by currents or shocks passing in the line wire, and the obstacle which retains the train of wheels is thus removed, the motion of the toothed wheel which carries the pin above mentioned, immediately liberates the hammer and allows the alarum to sound freely.

The thirteenth improvement consists in the application of the 1st and 2nd improvements above specified to the construction of electro-magnetic telegraphic or sympathetic clocks. These clocks resemble the step-by-step telegraphs in many particulars, differing from them only in the following :—1stly, the dial, instead of shewing the letters of the alphabet, shows the hours with their usual divisions; 2ndly, the power acting primarily on the axis of the second's hand, is communicated by a small train of wheels to the minute and hour hands. A rheotrope is adapted to the regulating clock for the purpose of alternately inverting the current proceeding from a voltaic battery instead of a rheotome, which merely determines a succession of currents in the same direction.

The fourteenth improvement consists in the adaptation of the 1st and 2nd improvements to electro-magnetic telegraphic registers or counters, instruments to indicate and number at a distance the periodically recurring motions of machines, the opening of gates or doors, &c. These differ from the clocks of the 13th improvement merely in the proportion of the wheels of the train, and the mode of division of the dials.

The fifteenth improvement consists in the substitution of magneto-electricity for voltaic electricity in order to produce the currents or shocks necessary to work such registers or counters. The axis of the armature of the magneto-electric machine is attached in a suitable manner to the machine, the motions of which require to be registered.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said Charles Wheatstone in the Great Seal Patent Office on the 2nd December 1858.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, CHARLES WHEATSTONE, of Hammersmith, in the County of Middlesex, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Second day of June, in the year of our Lord One thousand eight hundred and fifty-eight, in the twenty-first year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Charles Wheatstone, Her special licence that I, the said Charles Wheatstone, my executors, administrators, and assigns, or such others as I, the said Charles Wheatstone, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN ELECTRO-MAGNETIC TELEGRAPHS AND APPARATUS USED FOR TRANSMITTING SIGNS OR INDICATIONS TO DISTANT PLACES BY MEANS OF ELECTRICITY," upon the condition (amongst others) that I, the said Charles Wheatstone, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said Charles Wheatstone, do hereby declare the nature of the said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, that is to say:—

On January the 21st, 1840, a Patent was granted to myself and Mr. W. F. Cooke for "Improvements in Giving Signals and Sounding Alarums by Means of Electric Currents;" the Specification of this Patent contained the description of electro-magnetic telegraphs, in which the letters of the alphabet or other characters were indicated by a moveable hand pointing to them on a fixed dial, or by a moveable dial presenting the characters behind a fixed aperture. In one form of instrument the hand or dial was caused to advance step by step by the action of an electro-magnet on an armature of soft iron; in another, by the action of alternately inverted currents on magnetic needles, moved alternately in opposite directions.

Instruments, there called communicators, for working these signal telegraphs were also described, one acting by voltaic electricity, the other by magneto-electricity.

In the present Specification, I propose to describe various new improvements in electro-magnetic telegraphs constructed on the same general principles, and on other electro-magnetic instruments to which the same modifications are applicable.

The first part of my Invention relates to improvements in the signal instrument, the main object of which is to cause its movements to be effected with greater steadinesss, certainty, and rapidity than hitherto, and especially with electric currents or shocks of less energy than have hitherto been employed for such purpose, whether proceeding from a voltaic battery, a magneto-electric machine, or any other applicable source of electric power.

The first improvement is in the construction of the mechanism which converts the oscillatory motion of a magnetic needle or bar or the armature of an electro-magnet into the rotary step-by-step motion of the hand. This mechanism is constructed of great delicacy and lightness, so that a small force will cause it to act efficiently, and the improved forms of propelment which I have adopted are intended to cause the hand to move with regularity, so that either jumps or cessations of action shall be less liable to occur. I use the word propelment in contradistinction to escapement, which requires a maintaining power for its action. In one method, the two pallets which act on the propelling wheel have each an independent motion, moving as levers round fixed axes; their longer ends act on the inclined teeth of the wheel at opposite points of its circumference, and their shorter ends are connected by a hair spring. A pin attached to the axis of the magnetic needle or bar, or to the armature of the electro-magnet, acts in its alternate motion on each pallet, and presses it firmly against a tooth of the wheel, while at the same time the hair spring presses the other pallet against the opposite tooth, but so lightly and yieldingly as to offer no sensible impediment to its motion. By this construction, greater certainty and regularity in the motion of the hand is insured than when the pallets are rigidly attached to each other.

Figure 1 is a front view of a propelment constructed in this manner, and shewn on a magnified scale; *a* is a wheel with inclined teeth mounted on the axis of the index or pointer; and *b*, *b*, are two levers centred to the frame at *c*, *c*; at their lower ends they are connected together by a hair spring *d*. The electrical arrangement which actuates the propelment (that which I prefer to employ will be hereafter described) is applied so as to press the inclined ends or pallets of the levers *b*, *b*, alternately against the teeth of the wheel *a*, and thus a step-by-step rotary motion is communicated to the wheel with the index or pointer mounted on its axis. It will be seen that the action of the spring *d* is such as to keep the pallets constantly in contact with the propelled wheel; when the electrical arrangement presses one of them firmly against the wheel, thereby moving it a step forward, the other yields to let a tooth of the wheel pass, but yet bears sufficiently to prevent a sudden jump of the propelled wheel *a*. It will be seen that when the pallet has (by being pressed against the wheel) produced a forward step, it serves as a stop to prevent the wheel advancing more than one step, and also that the length of the step produced by each motion is such as to carry a tooth of the wheel just over the angle of the other pallet. In a second method, the axis of the propelling wheel, instead of being fixed, is attached to the end of a short lever, the other arm of which is acted upon by a pin connected with the axis of the magnetic needle or bar, or the armature of the electro-magnet. The two pallets which act on teeth at opposite points of the circumference of the wheel are fixed so that the rotary motion of the wheel is occasioned by the lever to which it is fixed being moved with it towards the two pallets alternately, the motion being limited by two fixed pins, against which the pallet wheel impinges at the opposite limits of its oscillation. Each pallet consists of a very light spring, placed tangentially to the circumference of the wheel, and readily yields to a tooth passing beneath it when the opposite tooth is propelled by the other pallet, and then falls in its place ready to propel the tooth which has passed beneath it. To prevent the oscillating motion of the wheel being communicated to the hand, the axis of the latter is detached from that of the former, and is caused to rotate by means of a driving pin attached thereto.

Figure 2 is a front view of this form of propelment. *a* is the axis of the electrical arrangement; it turns on centres on the frame, and carries an arm *b*, which is continued below its axis to balance its upper end; the toothed wheel *c* is mounted so that it can turn freely on its axis. The partial rotation, alternately in either direction, of the axis of the electrical arrangement carries the arm *b* from side to side, and with it the wheel *c*, until it is stopped by coming in contact with the adjustable screw stops *d*, *d*. In place of mounting the arm *b* directly on the axis of the electrical arrangement, a pin on this axis may be arranged to come in contact with the lower arm of the lever *b*; at each motion of the wheel *c* it is rotated half a tooth by the action of pallets formed on the ends of the air springs *e*, *e*, the pallets acting similarly to those in the propelment before described, that is to say, while one pallet is propelling the other, though still bearing on the wheel, yields to allow the tooth to pass.

Figure 3 is a side view of part of the arrangement, shewing the manner in which the rotary motion of the wheel *c* is communicated to the index or pointer.

f is the axis of the wheel; *c* and *g* is the axis of the index or pointer; they are as shewn, linked together at their ends, so that the one can assume an inclined position without carrying the other with it. On the axis *f* a driving pin *h* is fixed, and this passes up between two pins carried by a piece mounted on the end of the axis *g*; thus this axis is caused to partake of the rotary motion of the axis *f*, but not of its angular motion.

The second improvement is in the construction of the electro-magnetic arrangement employed to produce the motions of the step-by-step index and dial telegraphs, and is equally applicable to other forms of electro-magnetic telegraphs and alarums. Two magnetic needles or bars with their poles in opposite directions, are placed near each other on opposite sides and parallel to the axis, round which they move; two straight electro-magnets are placed one on each side of the axis of motion of the needles, and parallel thereto; when a current is transmitted through the coils of these electro-magnets in such manner that the adjacent poles of each shall have at the same time opposite polarities, the dissimilar poles of the two needles are simultaneously acted upon, so that each of their poles is attracted by one pole of one electro-magnet, and repelled by one pole of the other electro-magnet, the attracting and repelling actions all conspiring to move the axis in the same direction. Instead of being straight, the magnetic needles or bars may be curved inwards towards each other, so that their weight shall be thrown nearer the axis of motion. By this construction, the force of the electro-magnets is applied near the axis of motion of the magnetic bars instead of at a considerable distance from it, as is the case when electro-magnets are applied to the poles of a straight magnetized bar moving on an axis to which it is perpendicular; another of its advantages is, that the moving parts being balanced, the attraction of the residual magnetism remaining in the electro-magnets after the current has ceased, is sufficient to hold the needles with firmness, even in spite of concussions. Figure 4 is a plan, Figure 5 a side view, and Figure 6 a longitudinal section, of an electro-magnetic arrangement, constructed according to this improvement, and it is shewn combined with one of the propelments already described, so as to form a step-by-step instrument; Figure 7 shews the dial of this instrument *a, a*. Figures 4, 5, and 6, are two electro-magnets, of which the coils communicate with the line wire, so that when a current or shock passes therein it produces opposite polarities in the adjacent extremities of the magnets. Figure 8 shows the form of the pole pieces of these magnets; *b, b*, are two frames in which the magnets are mounted separately; they are connected to the base plate *c* of the instrument by screws *d, d*, which pass through slots in the plate *c*; *e, e*, are springs acting on the screws *d, d*, and tending to press them to the end of their slots, and to separate the electro-magnets as far as possible; *f, f, f, f,* are four small screws, the ends of which come in contact with the frames *b, b,* and by means of these the distance between the poles of the electro-magnets can be adjusted. Between the two electro-magnets an axis *g* is mounted on suitable pivots, so as to turn freely, and to this axis two magnetic needles *h, h,* are attached. The magnetic needles *h, h,* have at their adjacent ends opposite polarities, so that when a current or shock passes in the line wire, each of the electro-magnets attracts the two ends of one of the needles, and repels the two ends of the other, and these attractions and repulsions both tend to cause the axis to rotate in one or other direction according to the direction of the current or shock in the line wire. The arm which carries the pallet wheel of the propelment is mounted on the axis *g*, and it receives its motion and communicates it to the index or pointer in the manner already fully described, and there being in this case thirty signs on the dial, the pallet wheel should have fifteen teeth. *h* is a button placed at the top of the dial for the purpose of working the index or pointer round the dial to set it with the communicating instrument, if from any accident the position of the index of the one instrument should cease to correspond with that of the other; the button *h* works a spring fork *i*, which passes between two pins *j, j,* so that the prongs of the fork, when the button is not acted on, rest against the two pins; the axis of the pallet wheel passes between the prongs of the fork, and, when the button is partially turned, one of the prongs of the fork yields, and allows the other to come in contact with the axis and push it to its extreme position in one direction, so as to cause the index to advance one step; by moving the button in the other direction the index is caused to move another step, and so on; it will be seen that the prongs of the fork act as springs to bring the button to its central position when out of use.

While the principle of this electro-magnetic arrangement remains, it admits of various modifications. 1. The magnetic needles or bars may be inclined to each other at a small angle crossing at the axis of motion, their opposite poles being at opposite sides of the axis. 2. A single magnetic needle, balanced or unbalanced, may be employed in conjunction with two electro-magnets, or a single electro-magnet may be used in conjunction with two magnetic needles, the electro-magnet being placed on one side of the needles only, but neither of these constructions is as advantageous as that which I have already described. 3. Instead of the electro-magnets being parallel to the magnetic needles or bars, they may be curved, so that their two poles shall act, one attracting, the other repelling on the poles of the magnetic needles between them. Two curved electro-magnets arranged in this manner, each to act on one of the poles of each of the magnetic needles, will operate as efficiently as straight electro-magnets applied in the manner before described, but the arrangement is not so convenient. 4. Several such pairs of balanced magnetic needles may be fixed on the same axis, the poles of those adjacent being of opposite kinds, so that the planes in which they lie shall be at equal angular distances from each other. As many straight electro-magnetic bars as there are needles are placed parallel to the axis and in the angles between them, and the wires are so disposed that when the current in either direction passes through the coils, the joint attracting and repelling actions drive the needles to move round the axis in the same direction. In such arrangements there must be an even number of magnetic needles and electro-magnets.

Figure 9 is a plan, and Figure 10 an end view, of an arrangement in which four electro-magnets and four magnetic needles are employed. This instrument so nearly resembles that already described, that no detailed description of it will be necessary.

The third improvement consists in a modification of the apparatus of the second improvement before explained, which renders it capable of acting upon another circuit, so as alternately to invert the current originating from a voltaic battery interposed therein, in order to produce simultaneous and corresponding motions in another similar apparatus forming part of a signal telegraph at a distant station. For this purpose, the axis on which the magnetic needles or bars are mounted is made in two parts connected together by a piece of ivory or other insulating material, and one end of the axis is in connection with one pole of the battery, and the other end is in connection with the other pole of the battery of the magnetic needles or bars mounted on the axis; one is in metallic connection with one part of the axis, and the other is in metallic connection with the other part; and each of these needles is carefully insulated from the part of the axis with which the other is in metallic contact. When by the passage of a current or shock in the line wire, and consequently in the coils of the relay instrument, the magnetic needles or bars are caused to move, each of them comes in contact with a spring stop in connection with the wires of the circuit which the relay instrument is to complete, and this circuit is so completed. If now, by a current or shock passing in the line wire in a direction opposite to that which produced the first motion, the magnetic needles or bars are caused to move in the other direction, then they come in contact with two other spring stops, so as to complete the circuit in the opposite direction.

Figure 11 is a longitudinal section, and Figure 12 is a transverse section, of parts of an instrument constructed according to this improvement. The frame of the instrument is made in two parts *a* and *b*, which are separated from each other by insulating pieces *c*. Each part of the frame carries one of the standards which support the axis *d*. *e* is a piece of ivory, which insulates the two parts, of the axis the one from the other; *f*, *f*, are magnetic needles mounted between the poles of electro-magnets, as already shown and described; but these electro-magnets are not shewn in this Drawing. The needles *f*, *f*, are connected to their axis *d* by pieces of ivory *g*, *g*, and each of them is put in metallic contact with one part of the axis by a metallic strap *h*. The magnetic needles at one of their ends carry pins *i*, *i*, and these, when the needles are caused by a current or shock passing in the coils of their electro-magnets to move to either side, come in contact with two of the four spring stops *j*, *j*, and *k*, *k*; these stops are in connection respectively with the earth and with the line wire of the circuit into which the instrument is required to transmit currents or shocks, and the battery poles are connected to the two parts *a* and *b* of the frame, and consequently with the needles *f*, *f*. Thus it will be seen that when the needles move to one side they complete the circuit in one direction, and when to the other side in the opposite direction, that is to say, the instrument transmits into its circuit currents or shocks corresponding in direction to those which produce its motions.

The second part of my Invention relates to improvements in the communicator or apparatus for transmitting into the telegraphic circuit the proper number of currents or shocks required to indicate the various letters or characters, whether the source of power be a voltaic battery, a magneto-electric machine, an electro-magnetic machine, or any other kind of rheomotor, and to improvements in magneto-electric and electro-magnetic machines employed in conjunction therewith.

The fourth improvement is a new construction of the communicator when a voltaic battery is employed. It may be considered as a modification of that figured and described in the Specification of the Patent granted to myself and Mr. W. F. Cooke on the 21st of January 1840. It differs therefrom in the following particulars:—1stly, it alternately inverts the currents, instead of transmitting to the telegraphic circuit successive currents in the same direction; 2ndly, the alternation of conducting and insulating contacts are done away with; 3rdly, the letter circle or wheel, which in the former is solid, consists of a number of flexible spokes or radii, corresponding to the different letters or signs employed proceeding from a common centre, and each carrying at its free extremity a finger pin. When any letter is required to be indicated, the spoke on which it is engraved is moved by means of the finger pin at its extremity, so as to give the wheel a rotary motion, and is at the same time pressed down, so that a prolongation of the finger pin comes in contact with a fixed stop, and thus prevents the continuance of the motion. Instead of flexible spokes with fixed pins at their extremities, as here described, the rigid wheel may be retained, and stops or pins may be arranged on its circumference with springs so fixed to them that they may recover their original positions when the pressure of the fingers is removed. (This arrangement of letter circle is shown in the Drawings which illustrate my seventh improvement, and is explained in connection with that part of my Invention.)

The mechanism for producing the alternation in the direction of the currents admits of considerable modifications. I will describe one of the simplest and most efficient methods. A toothed wheel is fixed to the axis of the letter wheel of the communicator so as to rotate with it; this gears into a pinion, which during one revolution of the wheel rotates half as many times as there are letters engraven upon it. On the axis of the pinion is a small grooved disc insulated from it, and carrying a short pin fixed parallel to the axis. The axis of the pinion is placed between two spring bars insulated from each other, and as it rotates, the pin raises each of them alternately, and becomes respectively in metallic communication with them; while the pin is raising one spring bar, the other rests on the axis of the pinion; a spring also rests upon the insulated grooved disc of the pinion. The terminal wires of the battery are brought to binding screws in metallic communication with the axis of the pinion and with the spring bar which rests on the insulated disc respectively, and the terminal wires of the telegraphic circuit are brought to binding screws in metallic communication with the two spring bars on which the pin of the pinion acts.

Figure 13 is a side view, Figure 14 a vertical section, Figure 15 a plan, and Figure 16 an under side view, of an apparatus constructed according to this improvement. *a* is a wooden base, on the top of which the metal plate *b* is fixed by screws; this plate has a hole through its centre for receiving the flanged tube *c*, which is fixed to it by screws; *d* is an axis passing down through this tube; at the upper end of this axis the wheel *e* is fixed, and on the upper surface of this wheel the radial spring spokes *f*, *f*, are fixed; they are clamped down on to its upper surface by the covering plate *g*; each of the spokes *f* has a letter or sign engraved on it, and it carries a finger pin *h* at its end. When the apparatus is in use, and it is required to indicate a particular letter or sin on the dial of the receiving instrument, it is done by pressing down the finger pin of the spoke, having the same sign engraved on it, until it is stopped by coming against the periphery of the wheel *e*, and then by the finger pin the wheel is turned until it is arrested by the lower end of the pin coming in contact with the fixed projection *i*; by this motion of the wheel a sufficient number of currents or shocks is transmitted through the line wire to cause the index or pointer of the receiving instrument to pass from the letter or sign last indicated to the letter or sign which it is now desired to indicate; this it does in the following manner:—At the lower end of the axis *d*, the toothed wheel *j* is fixed; it drives the pinion *k* on the axis *l*, so as to cause it to revolve half as many times as there are signs engraved on the spring spokes; *m* is a metal disc, mounted on the axis *l*, but insulated from it; on this disc a spring *n* presses. The spring *n* is insulated from the other parts of the instrument, and is put in connection with one pole of the battery, and the other pole of the battery is brought into metallic connection with the axis *l*; *o* and *p* are two springs, which when left to themselves spring into metallic contact with the axis *l*, but are alternately lifted off it by the pin *q*, carried by the metal disc *m*. The springs *o* and *p* are insulated, and are respectively in metallic contact with the line wire and the earth; thus, for each revolution of the axis *l*, two currents or shocks, one in each direction, are transmitted into the line wire.

This construction of the communicator is equally adapted for working the step-by-step telegraphs, either when the direct current of a voltaic battery is employed, or when induction currents are made use of. In the latter case the terminal wires of the voltaic battery are to be brought to the binding screws which are in connection with the spring bars; the terminals of the primary coil of an induction apparatus are to be fastened in the binding screws which are in metallic communication with the pinion and its insulated disc, while the terminals of the telegraphic circuit are to be brought in permanent connection with the terminals of the secondary or induction coil; by this arrangement the battery circuit is never broken; when the current is not transmitted to the telegraphic wires, it continues to circulate for a moment in a short closed circuit; thus the spark which occurs on breaking the circuit is obviated.

The fifth improvement consists in the application of the letter circle described in the fourth improvement, in combination with a magneto-electric machine, instead of with a voltaic battery. The axis of the letter circle is so geared with the armature of the magneto-electric machine that during one revolution of the former the shocks are inverted as many times as there are letters engraved on the circle. Communicators thus constructed are efficient only when the magnets are of comparatively small dimensions.

Figure 17 is a longitudinal section of an instrument constructed according to this improvement. *a* is the letter circle constructed in all respects like the letter circle shewn at Figures 13, 14, 15, and 16; it is mounted on an axis *b*, which carries a toothed wheel *c*; this wheel drives the pinion *d* on the axis *e* of the armature *f* in such a manner that the axis *e* makes fifteen revolutions while the axis *b* makes one; this suits a step-by-step instrument having thirty signs on its dial; if this number be changed, a similar change must be made in the gear. *g* is a permanent magnet. One end of the coil of the armature is connected with the frame of the instrument, and the other end to the insulated metal disc *h* on the axis *e*; from this the current passes by the spring *i* to the insulated standard *j*, which is connected with the line wire; the frame of the instrument is connected with the earth. Thus, it will be seen that the armature is so actuated by the letter circle that the moving this through a space corresponding with one letter causes one effective current to pass into the line wire.

The sixth improvement consists of new methods of constructing the communicator when a magneto-electric or electro-magnetic machine produces the currents or shocks, which are transmitted by its means into the telegraphic circuit. In this improvement the armature of the permanent or electro-magnet is kept in continuous motion by the hand of the operator, or by being connected with any moving power, and finger stops corresponding with the letters on the dial of the telegraph being respectively pressed down, regulate the passage of the currents or shocks into the telegraphic circuit, for the purpose of acting on the detached telegraph. By this means, however large and powerful the magnet which is employed may be, the operator may act upon the finger keys with the same facility, which would not be the case were the motion of the armature itself to be arrested thereby. The two principal mechanical arrangements by which this improvement is effected are the following:—In the first construction, the axis of the armature of the magnet is independent of the axis which carries the index, but is capable of being geared thereto by the depression of either one of a series of finger stops or keys arranged round the apparatus, and corresponding with the letters of the alphabet; this action also disjoins a cross connection, and thus allows the currents generated in the coils of the armature, which were before confined to a short circuit to pass into the telegraphic line, and projects forward a lever corresponding with the stop or key into such a position that a spring catch carried by the axis of the index when it is brought opposite to it by the revolution of its axis strikes it, and by so doing it sets free the stop or key previously held depressed; on the release of the key the cross connection which diverts the currents from the telegraphic circuit is recompleted, and the axis carrying the arm with the spring catch is thrown out of gear with the axis of the armature; but while the index is passing from the point at which it is thrown into gear to the point at which it comes in contact with the lever projected forward by the stop or key, the requisite number of shocks or currents have passed into the telegraphic circuit. The gearing between the armature axis and the axis of the index is such that when it is in operation the index axis rotates at the same speed as the hand or index of the receiving instrument. In order that imperfect currents may not be thrown into the telegraphic circuit, the apparatus is so arranged that the axis of the index is not at all times thrown into gear with the armature axis immediately on the depressing of the stop or key. If the armature is not in a proper position for communicating a shock or current, the toothed wheel in connection with the index axis is prevented from falling into gear with the toothed wheel in connection with the armature axis until the moment at which the inversion of the current takes place.

Figure 18 is a side view of a communicator constructed in this manner; a portion of the case is removed in order to allow the arrangement of the apparatus to be clearly seen; Figure 19 is a plan of the same instrument as it appears with its case; Figure 20 is a transverse section of a portion of the instrument; and Figure 21 is a plan partly in section of the same parts. *a* is a magnet furnished with an armature *b*, arranged to revolve in front of its poles on the vertical axis *c*; this axis is driven by a band passing to the wheel *d*, to which rotary motion is given by hand. On the upper end of the axis *c*, a disc *e* is mounted, and this disc is is furnished with two pins which drive the toothed wheel *f* on the axis *g*, thus causing it to take two steps at each revolution of the axis *e*; the wheel *f* has thirty teeth. *h* is another wheel on the same axis; it is furnished with fifteen teeth, and is so fixed on the axis that its position thereon may be exactly adjusted. *i* is an axis mounted in the centre of the frame; it carries at its upper end an index or pointer *j*, which when the axis *i* is thrown into gear with the axis *g*, in the manner hereinafter explained, passes step by step round the dial, and points in succession to each of the letters and signs marked on it. These letters or signs have also each a corresponding finger key *k*, furnished with a spiral spring *l*, which constantly acts to press it upwards, but when one of these finger keys is depressed, it is held in that position by a corresponding lever *m*, the tail of which is forced into a notch in the stem of the key by its spring *n*; the depression of any one of the finger keys also acts on the end of one of the levers *p*, and by causing it to rock on its support *q*, it raises its inner end, and this pressing under the flange of the boss q^1, on the axis *i*, lifts it vertically in opposition to the spring *r*, which tends always to draw it downwards. On the axis *i* are two toothed wheels *s* and *t*, having fifteen and thirty teeth respectively; they are fixed together or formed in one piece, and mounted loosely on the axis, but they are prevented from turning independently of the axis by the pins *u* on the boss q^1, which enter holes in the wheel *t*, but they can slide longitudinally on the axis; *v* is a spring which has a tendency to force the wheels *s* and *t* to their highest position. When the axis *i* is lifted by depressing a finger key as before explained, the wheel *s* gears with the wheel *h*, either immediately, if the key happens to be depressed, when the teeth are properly placed, or if not, then after the wheel *h* has moved through a sufficient space to place its teeth in a suitable relative position, the wheel *s* being then projected upwards by the spring *v*. *w* is an axis on which a fork *x* is mounted; this embraces the wheel *s*, so that the rise and fall of this wheel causes the axis *w* partially to rotate; the rise of the wheel lifts the piece *y* out of the teeth of the wheel *t*, which with the axis *i* was thus previously locked. On the axis *w* a metal spring *z* is also fixed, and this by the rise of the wheel *s* is withdrawn from contact with the insulated knob A. The levers *m* which lock the finger keys, when depressed as already described, have, as will be seen by the Drawing, hooks formed at their ends, which when the other end of the lever falls into the notch in the key, project forward slightly, so that as the spring catch B, which is fixed on the axis *i*, is carried round by the revolution of the axis, it strikes the lever so projected forward, and withdraws its other end from the notch of the key, which then springs up, and allows the axis *i* to be drawn down out of gear with the axis *g*. The communication between the coils of the armature *b* and the instrument is made in the following manner:—On the axis *e* of the armature an insulated metal ring C, only shown in dotted lines in Figure 18, is mounted, and with this ring one end of the coils is in metallic connection; D is a metal spring constantly in contact with the ring C; the spring D is insulated from the frame, and is connected by a wire with the knob A; it is also connected with the line wire; the other end of the coil of the armature is connected with the frame of the instrument, and an electric communication is established between this and the earth. The action of the instrument is as follows:—At commencing, both the index of the communicator and the index of the receiving step-by-step instrument are set to the same sign, viz^t, the cross at the top of the dial; the armature is then caused to rotate, but so long as none of the finger keys are depressed, the currents or shocks do not pass into the line wire, but prefer the shorter path through the spring *z*, but as soon as a finger key is depressed, and the wheel *s* gears with the wheel *h*, the spring *z* passes out of contact with the knob A, and the currents or shocks then begin to pass into the circuit. As two effective currents or shocks are generated by each revolution of the armature, and as a revolution of the armature corresponds with two steps of the index or pointer *j*, it follows that an effective current or shock is transmitted for each step of the index, and consequently the communicator and the receiving instrument will keep pace the one with the other. This goes on till the spring catch B strikes the end of the lever *m*, corresponding to the finger key depressed; this liberates the key, throws the index axis out of gear, and re-establishes the short circuit for the currents; when another finger key is depressed the action is repeated. It will be seen from the arrangement of the wheel-work that it is impossible for imperfect currents to pass into the circuits when the wheel *h* has once been adjusted on its axis, for the gearing together of the wheels *h* and *s* can only take place when the armature is in one of two positions, both of which are arranged to be when the current or shock commences to be produced. Further, the gearing does not take place at either of these positions indifferently, otherwise currents in the wrong direction might be transmitted, but it can only take place when the armature is in the same position as it was when the wheels last fell out of gear.

In a second method of construction the arbor which is geared with the axis of the armature carries a toothed wheel; an arm to which the index is fixed moves freely round this arbor, and is carried with it when any tooth of the wheel is in contact with a spring catch at the end of the arm, and the telegraphic circuit is complete all the time this contact lasts. The index arm is separately stopped by pressing down either of the finger stops, while the arbor and all the other parts connected with it continues its motion, and the transmission of the currents to the telegraphic circuit remains interrupted so long as the motion of the arm is arrested.

As the circuit is not completed when the arm is released, but at the moment when the contact is made between the tooth of the wheel and the catch of the arm, which corresponds with the moment of the inversion of the current, imperfect currents are prevented from entering into the circuit. As in this construction the currents continue to pass into the telegraphic circuit so long as a key is not pressed down, a provision is made for keeping the stop which corresponds with the sign indicating the termination of a message, permanently depressed when required, and which at the same time completes the telegraphic circuit, omitting from it the coils of the armature of the magnet.

Figure 22 is a longitudinal section of a communicator constructed according to this second method; the instrument is not shown complete, but only those parts which are necessary for its explanation are indicated. *a* is an axis carrying an armature *b*; this axis is caused to rotate by hand or otherwise in front of the poles of a magnet, as in communicators already described; *c* is a pinion on the axis *a*, driving the toothed wheel *d* on the axis *e*, so that the axis *a* makes fifteen revolutions while the axis *e* makes one; *f* is a wheel also fixed on the axis *e*, it has fifteen teeth in its periphery, as is shewn in plan in Figure 23. *g* is an arm mounted loosely on the axis *e*, and insulated from it by the piece of ivory *h*; the arm *g* is also tipped with ivory at its other end; *i* is a spring catch mounted on the arm *g*, and so placed as to engage with the teeth of the wheel *f*; *j* is an index or pointer fixed to the arm *g* (but insulated from it), it travels round the dial *k*, and points in succession to the thirty letters and signs marked on it; this dial corresponds to that shown in Figure 19. *l* is one of a series of finger keys, of which there are thirty ranged round the dial, it is as is shewn enlarged in diameter at its upper end, and when one of these keys is held depressed the arm *g* comes in contact with it, and is stopped, but the revolution of the armature continues as before, the spring catch *i* giving way to allow the teeth of the wheel *f* to pass. The armature coils are connected with the instrument in the following manner:—One end of the coils is connected directly to the frame of the instrument, and the other end of the coils is connected with the insulated metal ring on the axis *a*, and from thence the metallic connection is continued by the spring *m* to the standard *n*; this is connected with the earth and also with the insulated standard *o*. When none of the finger keys are depressed, the spring catch *i* is in contact with the wheel *f*, and the currents or shocks pass from the frame of the instrument to the arm *g*, and thence by the spring *p*, which constantly bears on it to the insulated standard *q*, which is coupled up with the line wire, and all the currents or shocks produced by the armature thus pass into the circuit; but when a finger key is depressed and the arm *g* stopped, the spring catch *i* no longer remains in contact with the wheel *f*, and the circuit is broken, being re-established only as the teeth of the wheel *f* click in passing, but as these points correspond with the inversion of the currents or shocks, no effect is produced on the indicating instrument. It will be seen that imperfect currents or shocks cannot be introduced into the circuit, for the circuit can only be completed when the armature is in position to send a perfect current or shock in the direction required. The finger key which corresponds with the zero point is provided with a screw to fix it down so as to hold the arm *g* in the position shewn in the Drawing, and then a short circuit is completed by the spring *r* carried by the standard *o* coming in contact with the pin *s* carried by the arm *g*. When the instrument is in this position currents or shocks transmitted from a distant station do not have to traverse the coils of the armature. To avoid the necessity of locking the finger key corresponding with the zero point of the dial, a movement which has to be attended to by the operator, another contrivance is adopted by which any one of the finger stops being depressed, it remains so even when the finger is removed, until another stop is touched, when the former is restored to its normal position. This is effected by an endless chain passing round a series of friction rollers so placed that it forms a circle concentric with the circle in which the finger stops are arranged; the fingers stops are so constructed that when either of them is depressed it presses against the endless chain and tightens it, and when another stop is subsequently depressed, and bears in like manner against the chain, the flexure made by the first stop is obliterated and the stop restored to its normal position.

Figure 24 is a vertical section of a communicator constructed in this manner; Figure 25 is a horizontal section taken at the line 1, 1, Figure 24; and Figure 26 is a plan of the same. The instrument is so similar to that last described, that it will not be necessary to repeat the whole of the description. Some of the parts, which are similar to those described at Figures 22 and 23, are marked with the same letters. A, A, are finger keys, of which there are thirty, as before, but their form is considerably changed; they are ranged round the ring B, and fit into notches in the plate C; D, D^1, are other plates, they are notched to receive the lower ends of the keys A, A, and have between them small friction pullies E, E, round which a chain F passes; a top view of the plate D is shewn at Figure 27, and a similar view of the plate D^1, with the friction pullies and chain, at Figure 28. G, G, are small springs, there is one to each finger key; it is connected with the stem of the key at one end, and at the other end with the plate D; the ends of these springs have a tendency to spring from each other, so that when the key is up it tends to keep it up, and when down (in the position shewn by the dotted lines in Figure 24) to keep it down. The depression of one of the finger keys, besides acting on the apparatus, as already described, takes up the slack of the chain, and when another key is depressed it pulls on the chain, so as to raise the first against the resistance of its spring.

It is a peculiar character of these magneto-electric communicators, that none of their parts are mechanically connected with the signal telegraph of the transmitting station, as in some arrangements which have been previously proposed, but the former is complete in itself and entirely independent of the latter, except by its action upon it in consequence of the transmission of the currents through the conducting wire. The magneto-electric or electro-magnetic machine I usually adopt for the communicators forming the fifth and sixth improvements, is of the ordinary construction with a rotating armature. In this disposition four shocks or currents are available during each revolution of the armature, the first two following being in one and the same direction, and the next two following being in the opposite direction. No contrivance is here required to invert or to stop out the alternate currents the two successive currents in the same direction (the first only of which is effective) give additional security that the index of the telegraph shall advance a single step.

Either of the following new forms of the magneto-electric machine, constituting the seventh, eighth, and ninth improvements, may be substituted for the one above mentioned.

The seventh improvement is a modification of the magneto-electric machine, in which, instead of the armature revolving before the poles of a magnet, it is caused alternately to approach to and recede from them by means of a cam, fixed to a wheel, or by other suitable means. If a single magnet is employed a contrivance for alternately inverting the direction of the currents must be had recourse to; but this is unnecessary when the armature oscillates between the poles of two similar magnets so disposed, that the currents shall pass through the circuit in opposite directions, according as the armature moves towards one or other magnet. This method may be advantageously applied to the communicator of the fifth improvement, as the motion of the letter wheel may be more immediately and certainly stopped at any required point, in consequence of there being no momentum generated by the rotation of the armature.

Figure 29 is an exterior view, and Figure 30 is a transverse section, of a magneto-electric machine constructed according to this improvement. *a* is a letter circle mounted on a vertical axis; it is not furnished with flexible spokes, as the letter circles already described, but with keys *b*, *b*, which correspond in number with the spokes for which they are substituted, although, to avoid confusion, but two of them are shown in the Drawing. These keys *b*, *b*, pass through sockets in the periphery of the letter circle *a*, and they have springs *c*, *c*, which press them upwards; when they are depressed by hand, they project below the circle *a*, and when the circle is turned round on its axis, the lower part of the key comes against a fixed projection, and stops the circle at the required point. On the axis of the letter circle a cam *d* is mounted; this cam is shewn separately at Figure 31. *e* is an armature; it is attached to the plate *f*, and this is carried by one end of the lever *g*, the axis *h* of which is carried by the standard *i*; the upper end of the lever *g* is furnished with a small friction pulley, and enters the groove in the face of the cam; the cam has fifteen rises and falls, and the extremes in both directions correspond with the commencement of a fresh current or shock; hence thirty are produced by one revolution of the cam. The permanent magnets *h* are placed with their similar poles opposite each other, so that the successive currents are in opposite directions.

The eighth improvement consists of a construction of the magneto-electric machine, in which neither the magnet nor the coil of wire is put into motion, but only the soft iron core which is enveloped by the wire. A coil of insulated wire is fixed, and within it is fitted a cylindrical core of soft iron capable of rotating on its axis without carrying the coil with it. The opposite ends of this soft iron core have lateral prolongations also of soft iron; these are of equal length, are at equal angular distances from each other, and extend over the ends of the coil so as to be brought in close proximity to the poles of a magnet, those at opposite ends to opposite poles. On causing the core to rotate once, as many double currents are produced in the coil as there are prolongations on each end of the soft iron cylinder. Instead of a single magnet several may be arranged with their poles in two parallel circles, and placed at distances from each other corresponding with the distances of the prolongations; by this means the strength of the currents is considerably augmented. If the poles of the magnets contained in the same circle are similar, the successive currents are alternate in direction and unequal in intensity; but if the poles are alternately dissimilar, two currents in one direction are followed by two currents in the opposite direction available for the purpose required; in the latter case the number of the magnets must be even, and the angular distances of the prolongations must be double the angular distances of the magnetic poles, so that they shall not be at the same time opposite adjacent magnets.

Figure 32 is a plan, and Figure 33 a vertical section, of a magneto-electric machine constructed according to this improvement. *a*, *a*, *a*, are six permanent magnets arranged round in a circle with their poles directed inwards; the centre of the circle is occupied by the axis *b*, and on this is mounted the cylindrical core of soft iron *c*; this core is furnished at each end with three projections *d*, *d*, which are in fact the armatures of the magnets, and is surrounded by a fixed coil *e*. The axis *b* is driven by a band from the hand-wheel *f*, and thus the projections from the core are caused to pass successively in front of the poles of the magnets. In some cases I modify this arrangement in the following manner:—In place of employing a single stationary coil *e*, and that in connection with the armatures, I surround each of the poles of the magnets *a* (the arrangement of magnets shewn at Figure 32 being still retained) with such a coil, or, what is better, I fix a short cylinder of soft iron on each of the extremities of the magnets, and surround these with the coils. These coils are all coupled up together, so as to deliver the currents or shocks induced in them into a single circuit. The magnets are furnished with armatures, one for each magnet, and these armatures are fixed on an axis corresponding with the axis *b*; thus, when the axis revolves they are carried in succession before the poles of the magnets or the soft iron continuations of the magnets, and currents or shocks are thus induced in the stationary coils.

The ninth improvement consists in substituting for a single magnet and armature in any of the magneto-electric machines employed for working telegraphs, several magnets and armatures so arranged that the instantaneous currents or shocks originated by each shall be produced simultaneously, and pass through the same conducting wire. A number of small magnets and armatures thus combined will produce a more efficient result than a single magnet and armature of proportionate dimensions. A convenient arrangement for carrying out this improvement is to gear together several magneto-electric machines so that the armatures of all of them shall revolve at the same speed and occupy at all times the same angular positions with respect to their magnets; the wires of the coils of all the armatures are coupled up to one wire, from which the currents or shocks are led away as if a single magneto-electric machine were employed. Electro-magnets may be substituted for permanent magnets in any of the modes of construction described as the seventh, eighth, and ninth improvements.

The third part of my Invention relates to improvements in electro-magnetic alarums, clocks, and registers or counters.

The tenth improvement consists in the application of the electro-magnetic arrangements described under the second head of my improvements to the withdrawal of detents for the purpose of permitting alarums to sound. The manner in which I prefer to make this application is shewn at Figures 34 to 40, herein-after described.

The eleventh improvement consists of appropriate mechanism to prevent the detent of an electro-magnetic alarum from escaping until several currents or shocks have been sent through the circuit, and consequently until the magnetic bars have moved to and fro several times. For this purpose the electro-magnetic apparatus is caused to actuate a species of escapement, which at each movement allows to escape one tooth of a short rack in connection with the alarum. By this arrangement one or more accidental jars will not cause the detent to escape. The mechanism above mentioned is also shewn at Figures 34 to 40, herein-after described.

The twelfth improvement consists of an appropriate mechanism to prevent the hammer of a bell from moving unless the magnets are acted upon by the electric force. The sounding of the bell is thus rendered independent of accidental shakes or jolts. For this purpose a pin is fixed to the periphery of the toothed wheel, which gives vibratory motion to the hammer in such a position that just as the motion of this wheel is arrested, when the alarum ceases to sound, the pin acts on a catch, and places it so as to restrain or limit the vibrations of the hammer arising from concussions to which the instrument may be subjected. When the alarum is next acted on by currents or shocks passing in the line wire, and the obstacle which retains the train of wheels is thus removed, the motion of the toothed wheel which carries the pin above mentioned immediately liberates the hammer, and allows the alarum to sound freely.

Figure 34 is a front view (with part of the case removed) of an alarum arranged according to the tenth, eleventh, and twelfth improvements; it is shown contained within the base of a step-by-step instrument, such as I have before described; Figure 35 is an end view; Figure 36 is a plan; Figure 37 is an under side view; and Figure 38 a back view of the same; Figure 39 is a longitudinal section taken at the line 1, 1; Figure 36 and Figures 40 show some of the parts separately. *a* is a barrel containing a spring which is wound up from time to time by the handle *b*; a^1 is a toothed wheel on the drum *a*, it drives a pinion *c* on the axis c^1; on this axis is also the wheel c^2, which, by means of its inclined teeth acting on inclines on the vertical axis *d*, gives motion to the hammer *e* in the usual manner, when the train of wheels is set free; c^3 is an arm on the axis c^1, and which rests on the pin *f* on the axis f^1, so that the alarum cannot sound until this axis f^1 is allowed to turn; it is retained (till set free by the electro-magnetic apparatus) by the arm f^2, the end of which rests under the axis *g*; this axis is flattened at g^1, and the arm f^2 can only pass when the axis *g* is turned so as to bring this flattened part opposite its end; g^2 is an arm carried by the axis *g*, it has three teeth formed at its end, as is shewn on a larger scale at Figure 41; *h* is the axis of an electro-magnetic arrangement, similar to that already described as actuating the propelment of the step-by-step instrument; on this axis the short arm h^1 is mounted, and it carries two pins h^2, h^2, which act in the following manner:—The arm g^2 being at its highest position, and its first tooth being pressed down upon the upper pin h^2 by the spring g^3, the first motion of the axis *h* allows this tooth to descend on to the lower pin h^2; the motion of the axis in the opposite direction allows this tooth to escape between the pins h^2, h^2, and then the second tooth of the arm g^2 descends on to the upper pin h^2, and so by successive motions of the axis h the whole of the teeth of the arm g^2 are enabled to escape; the axis g then turns by the pressure of the spring g^4, so as to allow the end of the arm f^2 to pass; the arm f^2 rises sufficiently to allow the arm c^3 to pass the pin f, and is then immediately brought down again by the spring i, as soon as the arm c^3 escapes the alarum commences to sound; c^4 is a cam on the axis c; as that axis revolves it acts on the lever j, so as to cause it to raise the arm g^2 to its former position; in consequence of the form of the teeth on the arm g^2, and of the pins h^2, h^2, they pass each other freely when the arm g^2 is moving upwards. By this motion the arm f^2 is again locked, and when the arm c^3 again comes against the pin f, the motion of the train of wheels is stopped; c^5 is a pin on the wheel c^2, which just as the alarum ceases to sound raises the catch k, in which a notch k^1 is formed; into this notch the stud d^1 on the axis d drops, and thus the oscillation of the hammer is limited. l is a handle which actuates the contact maker l^1, for the purpose of putting either the step-by-step instrument or the alarum into circuit as may be desired; this contact maker is of an ordinary description; there is a cam l^2 on the same axis, which when the alarum is turned out of circuit prevents the possibility of the arm g^2 descending.

The thirteenth improvement consists in the application of the first and second improvements above specified to the construction of electro-magnetic telegraphic or sympathetic clocks. These clocks resemble the step-by-step telegraphs in many particulars, differing from them only in the following:—1stly, the dial instead of showing the letters of the alphabet shews the hours with their usual divisions. 2ndly, the power acting primarily on the axis of the second's hand is communicated by a small train of wheels to the minute and hour hands. A rehotrope is adapted to the regulating clock, for the purpose of alternately inverting the current proceeding from a voltaic battery instead of a rheotome, which merely determines a succession of currents in the same direction.

This arrangement is fully illustrated by the step-by-step instrument, Figures 4, 5, 6, 7, and 8; the only changes are that the pallet wheel has thirty teeth in place of fifteen (if the regulating clock transmits one current or shock per second), and that the pallet wheel, as before mentioned, actuates a train of wheels as in an ordinary clock.

The fourteenth improvement consists in the adaptation of the first and second improvements to electro-magnetic telegraphic registers or counters, instruments to indicate and number at a distance the periodically recurring motions of machines, the opening of gates or doors, &c. These differ from the clocks of the thirteenth improvement merely in the proportion of the wheels of the train and the mode of division of the dials. These I arrange according to the circumstances of the case, but a convenient arrangement of the dials is that adopted in gas meters, where the first dial indicates units, the second tens, the third hundreds, and the fourth thousands; the pallet wheel may have 15 teeth, and then the gearing of the units' axis, index, or pointer will be arranged to increase the speed three times, and the gearing to the tens' index to decrease the speed, so that the tens' index may make one revolution for one hundred steps, or $3\frac{1}{3}$ revolutions of the pallet wheel.

The fifteenth improvement consists in the substitution of magneto-electricity for voltaic electricity, in order to produce the currents or shocks necessary to work such registers or counters. The axis of the armature of the magneto-electric machine is attached in a suitable manner to the machine, the motions of which require to be registered. For example, if it be the openings of a door that it is desired to register, I attach a permanent magnet to the door, and an armature with suitable coils to the frame. When the door is shut the poles of the magnet come close up to the armature, and when the door is opened and the magnet and armature separated, a current or shock passes through the coils of the armature, and causes the units' index of a counter, such as before described, to move one step; in a similar manner the strokes of a steam engine may be counted and indicated at a distance, and the improvement may be applied to many other similar uses, as will be clearly seen from the above description.

Having thus described the nature of my said Invention and the manner of performing the same, I would have it understood that I do not confine myself to the exact details described, as the mechanical arrangements may be much varied without departing from my Invention. What I claim, is,—

First, the methods of arranging the propelment of a step-by-step receiving instrument, described as the first improvement.

Second, the methods of constructing the electro-magnetic arrangement employed to produce the motions of step-by-step index and dial telegraphs, described as the second improvement.

Third, the modifying the electro-magnetic arrangement of the second improvement so as to render it capable of acting upon another circuit, so as alternately to invert the current originating from a voltaic battery interposed therein, as herein described.

Fourth, the arranging, as herein described, the communicator or instrument employed to transmit currents derived from a voltaic battery into the telegraphic circuit, or into the primary coil of an induction apparatus, the secondary coil of which is in connection with the telegraphic circuit.

Fifth, the method of arranging the magneto-electric communicator described as the fifth improvement.

Sixth, the arranging communicators as herein described for transmitting into a telegraphic circuit, currents or shocks produced by magneto-electric or electro-magnetic machines in continuous action, in a suitable manner to actuate a step-by-step receiving instrument included in the telegraphic circuit, each such instrument consisting of a series of finger keys, equal in number and corresponding with the letters and signs on the dial of the step-by-step receiving instrument; these keys being so arranged that when acted on they cause such a number of efficient currents or shocks to pass into the telegraphic circuit as is required to move the index or pointer of the receiving instrument from the position in which it last stopped to the letter or sign corresponding with the key acted on.

I also claim the method of preventing imperfect currents or shocks from passing into the telegraphic circuit by so arranging such communicators as herein-before described, that whatever may be the position of the parts of the magneto-electric or electro-magnetic machine, when a finger key is acted on, the coils of the machine may not be put into electric communication with the telegraphic line until the parts of the machine are in a proper position for communicating an efficient shock or current.

I also claim the so connecting together the finger keys that the depression of or the acting on any one of them, may restore to its original position the key last operated on.

Seventh, the method of arranging a magneto-electric machine described as the seventh improvement.

Eighth, the method of arranging a magneto-electric machine described as the eighth improvement, that is to say, the arranging such machines with stationary coils combined with a series of armatures, which are in succession caused to move past the poles of a magnet or a series of magnets, as herein-before described.

Ninth, the combining or gearing together a number of magneto-electric machines in the manner herein-before described as the ninth improvement.

Tenth, the application of the electro-magnetic arrangements described under the second head of my improvements to the withdrawal of detents for the purpose of permitting alarums to sound.

Eleventh, the application of mechanism to electro-magnetic alarums to prevent the detent from escaping until several currents or shocks have been sent through the circuit, as herein described.

Twelfth, the application of mechanism for retaining the hammer of electro-magnetic alarums, as herein described.

Thirteenth, the application of the propelments and the electro-magnetic arrangements described as the first and second improvements to electro-magnetic or sympathetic clocks, as herein described.

Fourteenth, the application of the propelments and the electro-magnetic arrangements described as the first and second improvements to telegraphic registers or counters, as herein described.

Fifteenth, the substition of magneto-electricity for voltaic electricity, in order to produce the currents or shocks necessary to work telegraphic registers or counters, as herein described.

In witness whereof, I, the said Charles Wheatstone, have hereunto set my hand and seal, this Thirtieth day of November, in the year of our Lord One thousand eight hundred and fifty-eight.

C. WHEATSTONE. (L.S.)

Witness,
JNO. ALCOCK.

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A.D. 1858. June 2. No. 1241.
WHEATSTONE'S SPECIFICATION.

(10 SHEETS)
SHEET 1.

FIG. 1.

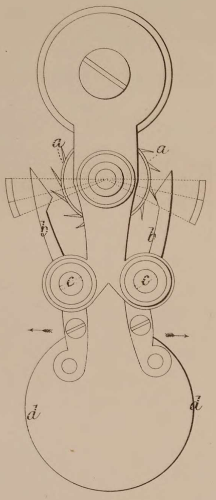
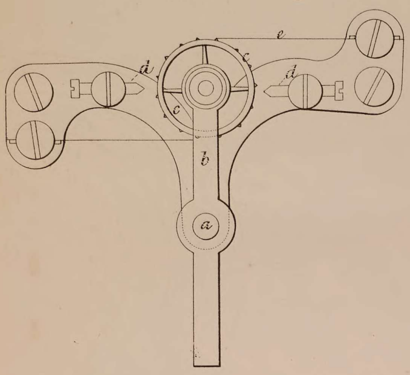


FIG. 2.



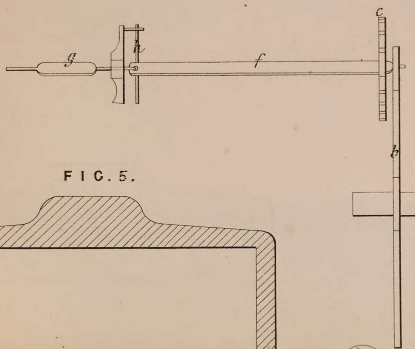


FIG. 8.

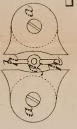


FIG. 4.

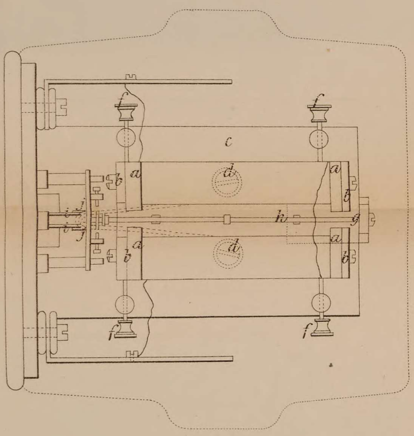


FIG. 5.

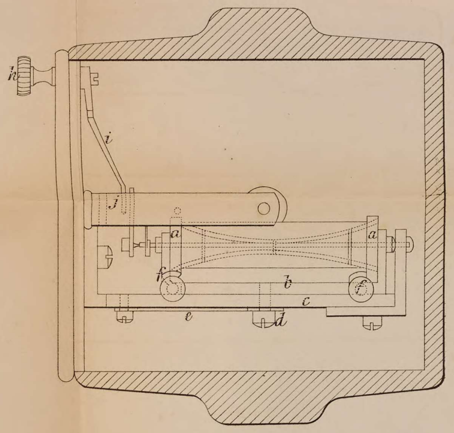


FIG. 6.

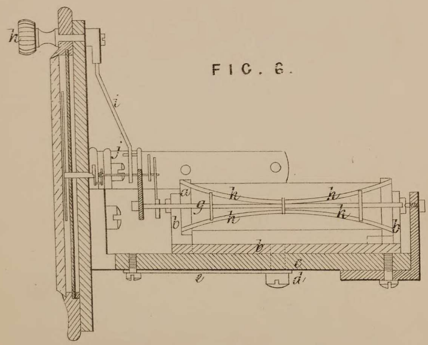
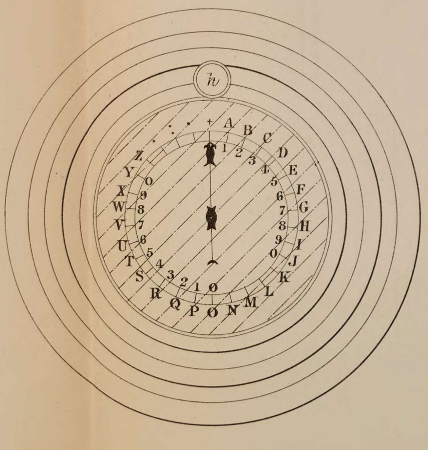


FIG. 7.



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WHEATSTONE'S SPECIFICATION.

(10 SHEETS.
SHEET 2.

FIG. 9.

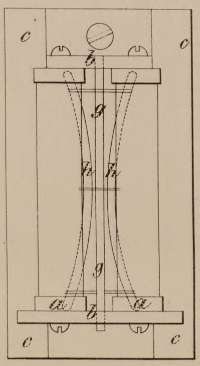


FIG. 10.

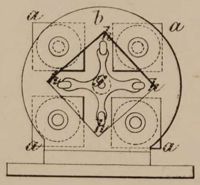


FIG. 11.

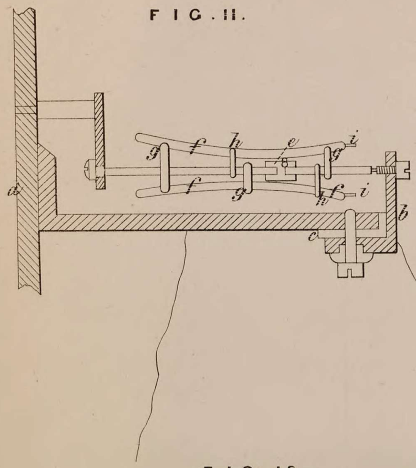
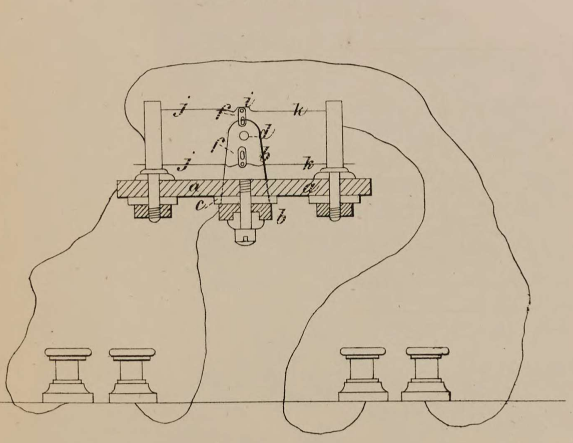


FIG. 12.



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SHEET 3

FIG. 13.

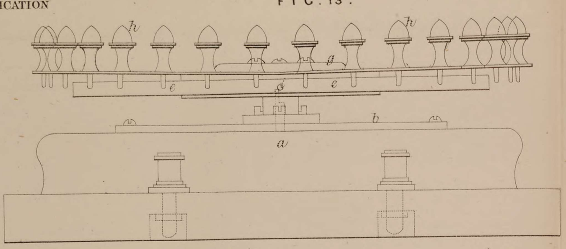


FIG. 14.

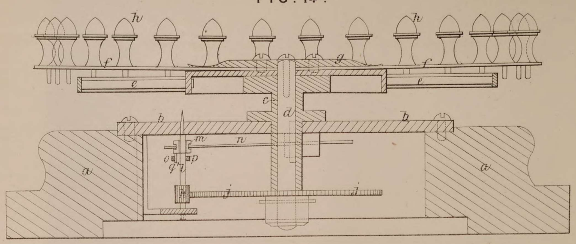


FIG. 15.

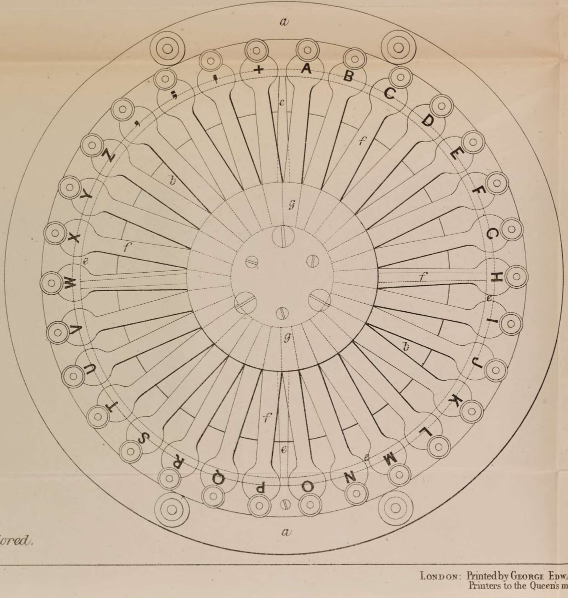
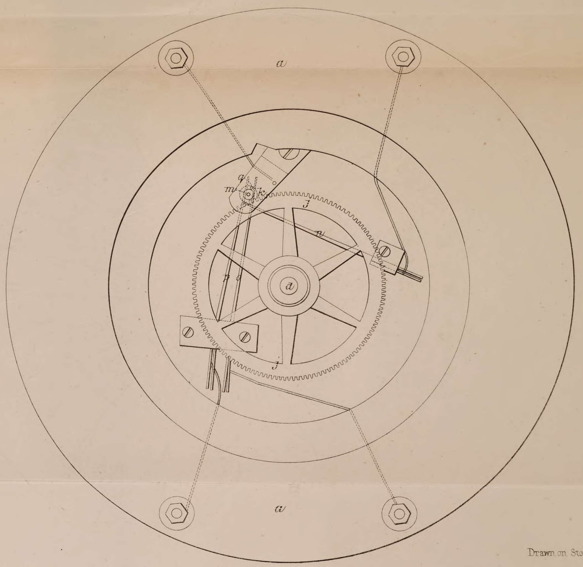


FIG. 16.



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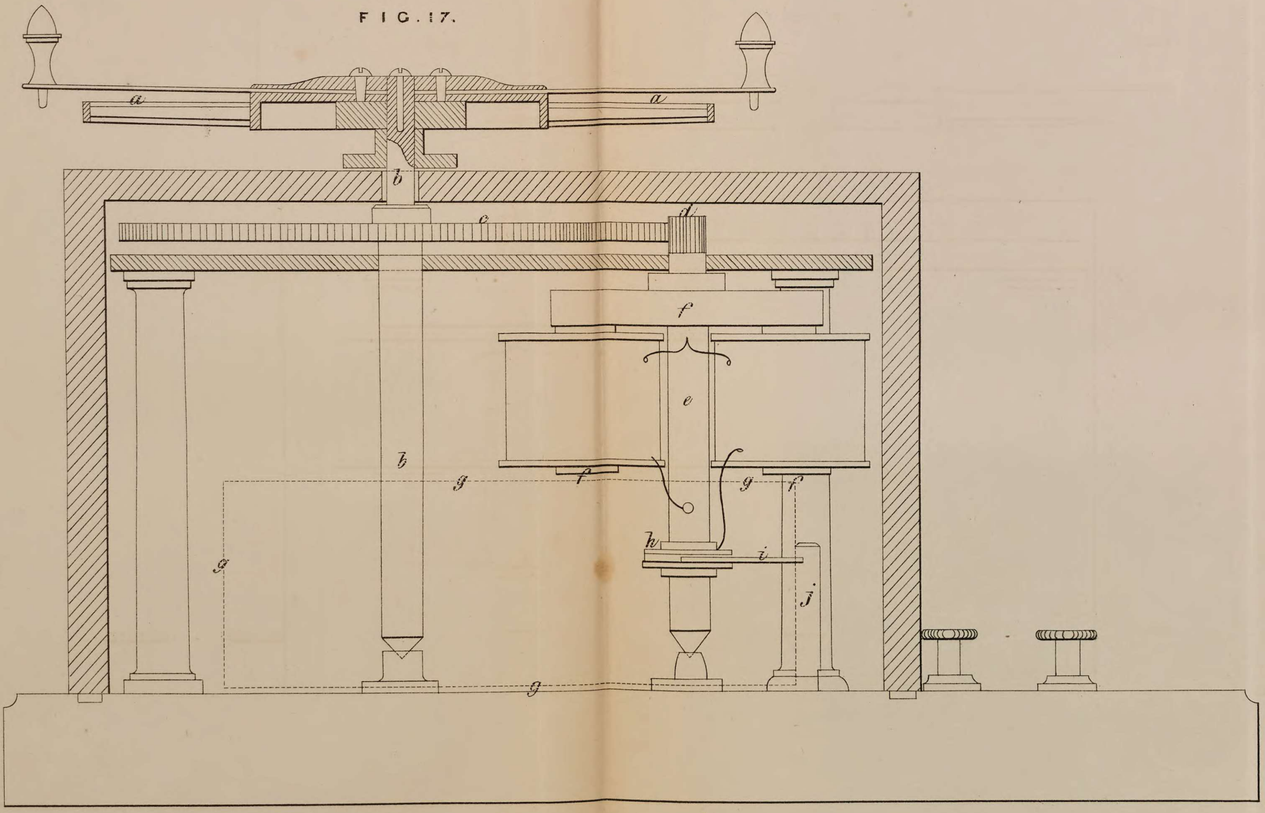
SHEET 4.

FIG. 17.



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SHEET 5.

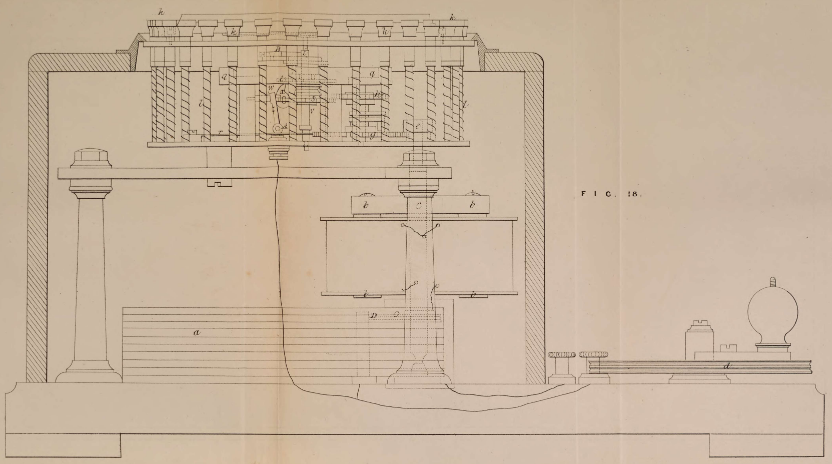


FIG. 18.

FIG. 20.

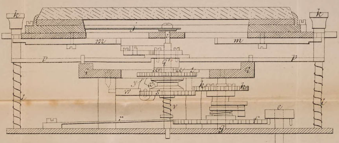


FIG. 19.

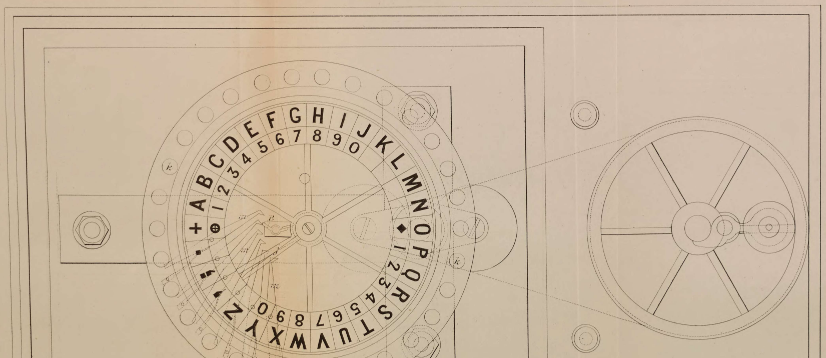
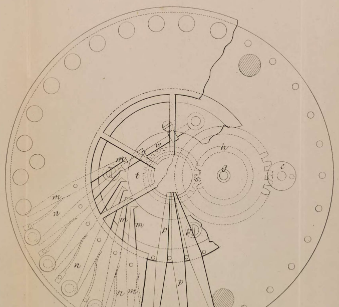
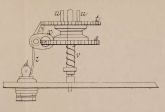


FIG. 21.





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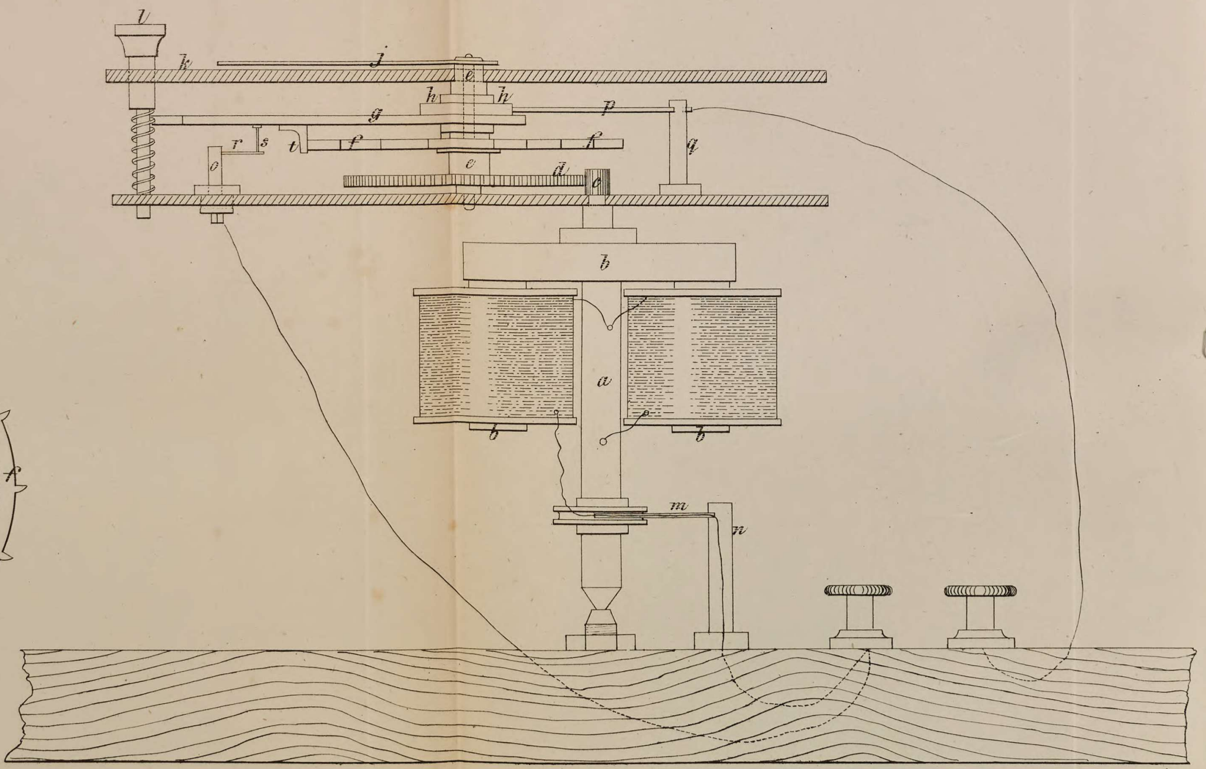
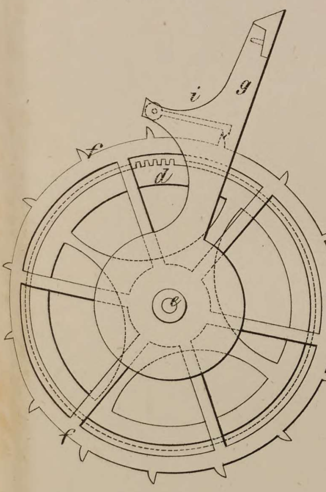
(10 SHEETS.)
SHEET 6.

F I G. 22.



F I G. 23.



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SHEET. 7.

FIG. 24.

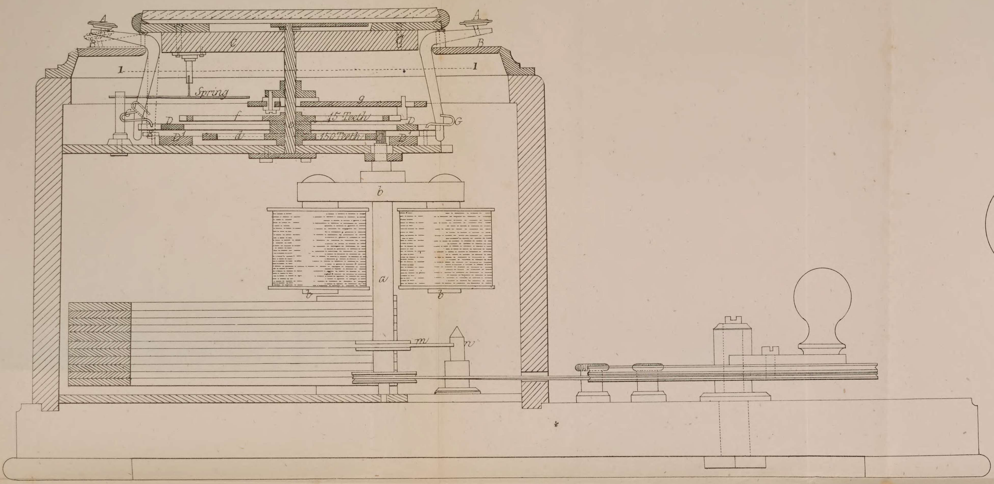


FIG. 26.

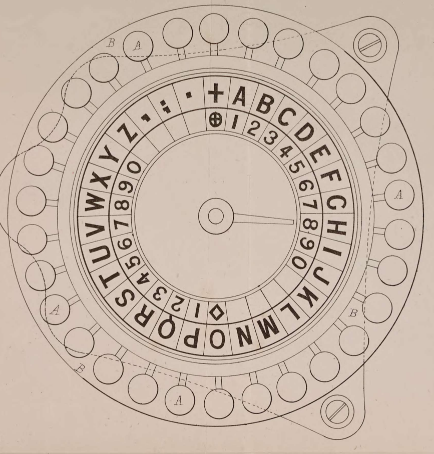


FIG. 25.

Vertical Section taken at the dotted line 11 in Fig 24.

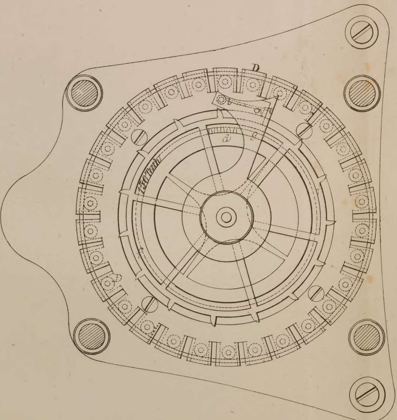


FIG. 27.

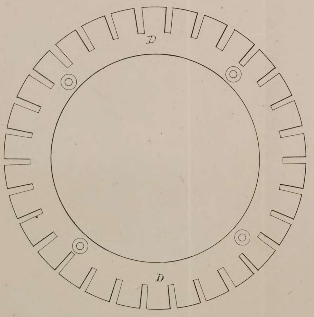
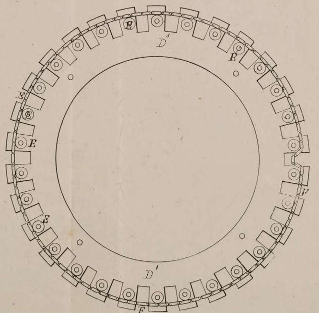


FIG. 28.



The filed drawing is colored.

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Printers to the Queen's most Excellent Majesty. 1858.

A.D. 1858. June 2. Nº 1241.
WHEATSTONE'S Specification.

(10 SHEETS)
SHEET 8.

FIG. 31.

FIG. 29.

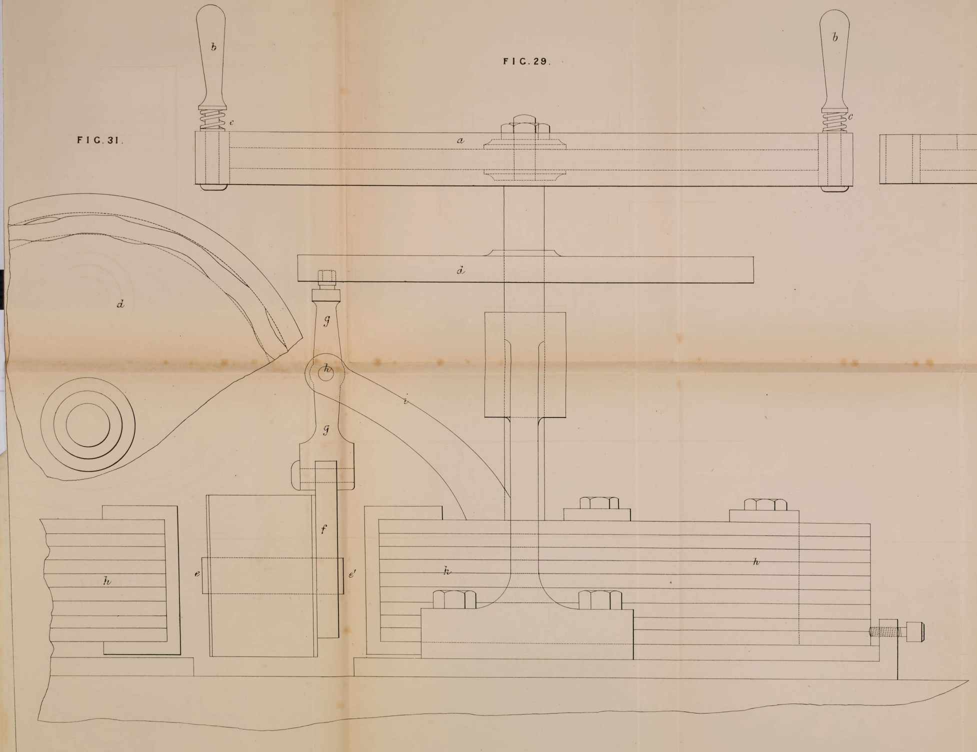
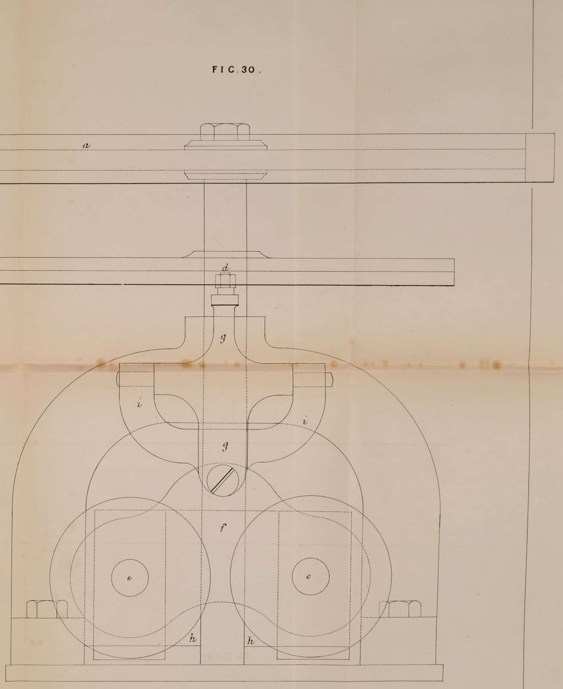


FIG. 30.



The filed drawing is colored.

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Printers to the Queen's most Excellent Majesty. 1858.

A. D. 1858, June 2, Nº 1241.
WHEATSTONE'S SPECIFICATION.

FIG. 33.

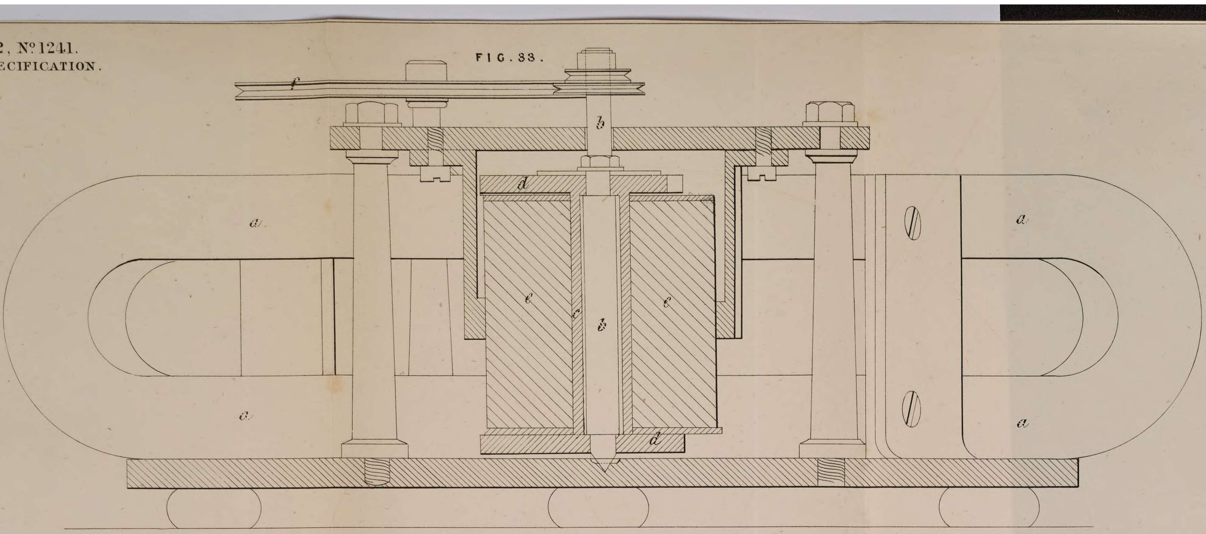
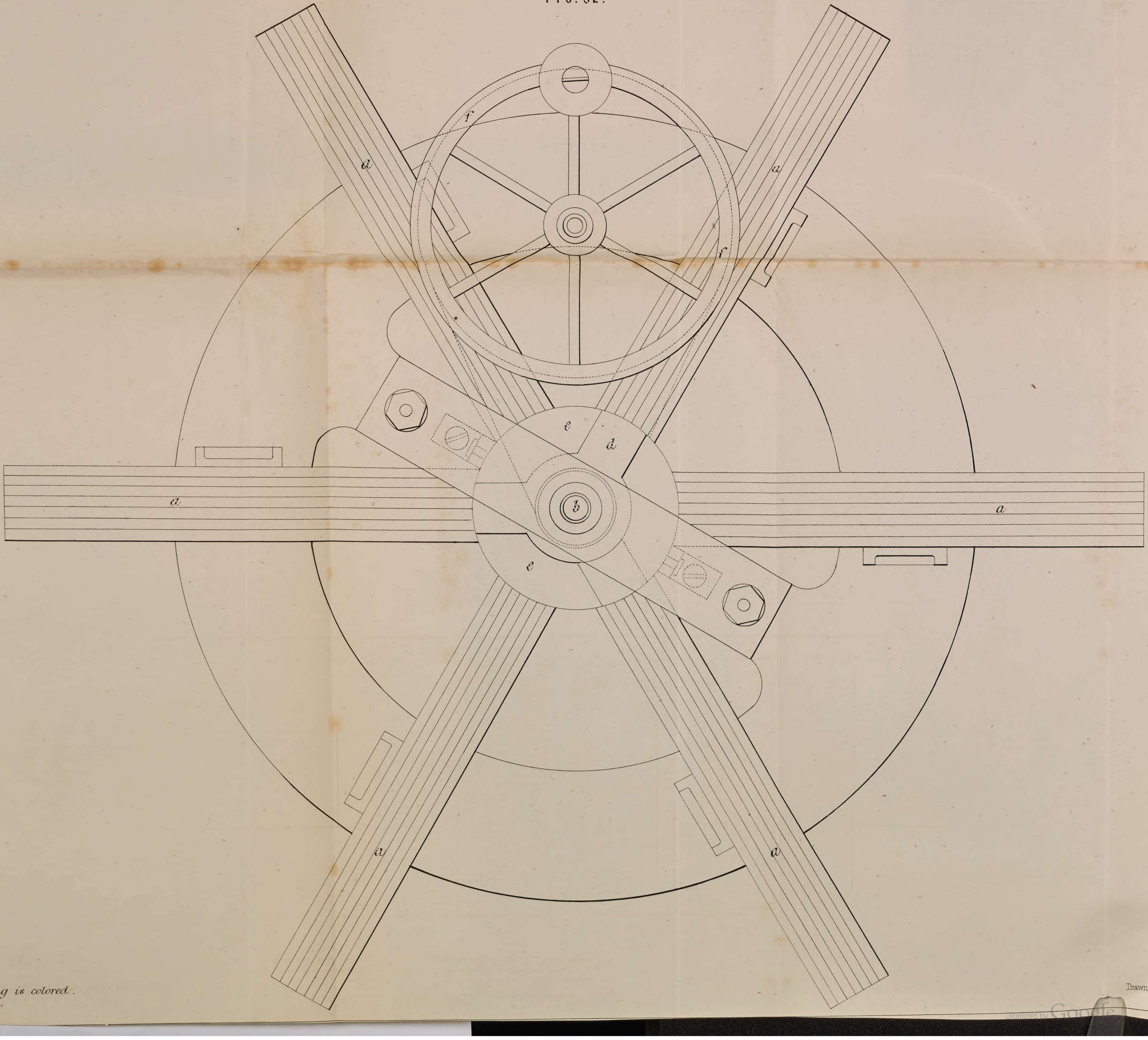


FIG. 32.



The filed drawing is colored.

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FIG. 34.

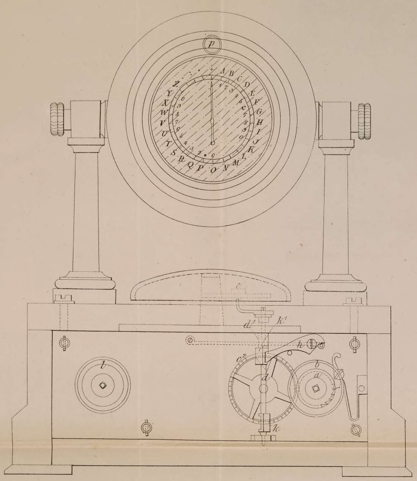


FIG. 35.

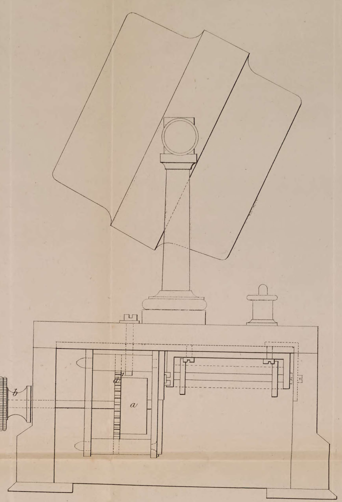


FIG. 38.

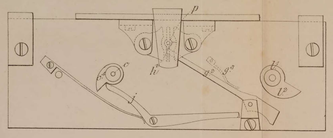


FIG. 39.

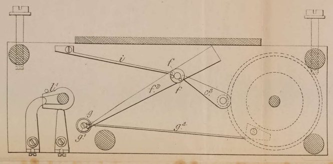
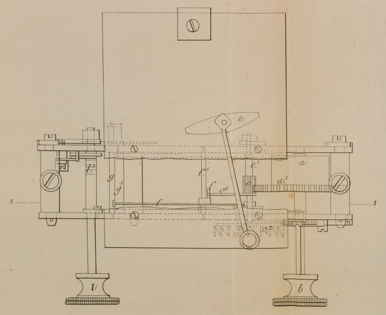


FIG. 36.



FIGURES 40.

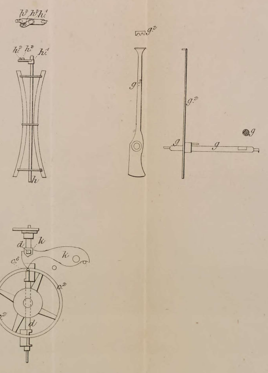


FIG. 37.

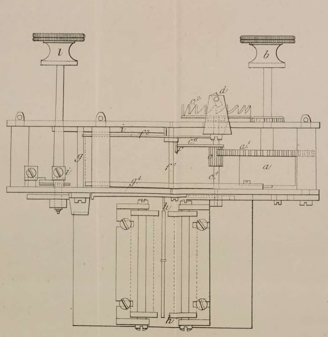
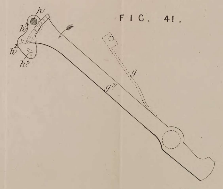


FIG. 41.



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